Big Data + Supply Chain Management

Examining Next Generation SCM Technologies

Levi Joseph

TC 660H

Plan II Honors Program

The University of Texas at Austin

May 11th, 2016

Dr. Genaro Gutierrez

Department of Information, Risk, and Operations Management

Supervising Professor

Dr. Michael Hasler

Department of Information, Risk, and Operations Management

Second Reader

Thesis Abstract

Author: Levi Joseph

Title: Big Data + Supply Chain Management: Examining Next Generation SCM Technologies

Supervisors: Dr. Genaro Gutierrez, Dr. Michael Hasler

My main thesis question is the following: "what are the ways in which Big Data technologies might impact Supply Chain Management?" I will also seek to address a secondary, more broad question if possible: "what are the societal implications of the increased use of Big Data technologies?" Chapter 1 will introduce Supply Chain Management (SCM), Big Data, and their junction. It will then provide operational definitions for both "Supply Chain Management" and "Big Data" by placing the subject areas in their respective historical and economic contexts.

I will then attempt to answer my thesis question by focusing on two core subject areas. Chapter 3 will cover Block Chain integration, a bleeding edge and very trendy topic. It will provide a history and overview of the technology, and will suggest several potential SCM use cases. Chapter 4 will focus on a core SCM process that is ripe for Big Data disruption, Sales and Operations Planning (S&OP). I will provide a overview of the subject area, and will seek to enumerate the ways in which improved forecasting and planning technologies may prove disruptive. Finally, Chapter 5 will consider some of the societal implications of the increased adoption of Big Data technologies across industries.

My primary advisor, Professor Genaro Gutierrez, teaches Supply Chain Analytics at the undergraduate and graduate level, while my second reader, Professor Michael Hasler, teaches Procurement and Operations Management at the undergraduate and graduate levels (in addition to directing the Masters in Science of Business Analytics Program).

Acknowledgments

Genaro Gutierrez, PhD

Michael Hasler, PhD

Frank and Annette Joseph

Table of Contents

I. Introduction

"Information is the oil of the 21st century, and analytics is the combustion engine."

- Peter Sondergaard, Senior Vice President, Gartner Research

The Age of Analytics: Finding the Signal in the Noise

The "Age of Analytics" is upon us, and it has not arrived by surprise or without hype (Bughin et al. 2016). In fact, the McKinsey Global Business Institute has been touting Big Data's transformational potential since at least 2011, when it predicted that "large data sets – so-called 'Big Data' - will become a key basis of competition, underpinning new waves of productivity growth, innovation, and consumer surplus" (Manyika et al. 2011). The accompanying hype, as with any new and potentially-disruptive technology, has been enormous. The Harvard Business review named the "Data Scientist" role – individuals who are tasked with turning vast tracts of information into valuable insights - as the "sexiest job of the 21st century" (Patil et al. 2012). Numerous masters programs, massive open online courses (MOOCs) and bootcamps have popped up to meet the "talent gap" in analytics, as nearly "40% of companies" struggle to find the analytics talent they seek (Olavsrud 2015).

The hype surround Big Data and Analytics has been criticized for being just that: hype. One popular joke that has made rounds on social media platforms states that "a data scientist is just a data analyst who lives in California," while others label "Big Data" and related terms such as "machine learning" as nothing more than marketing buzzwords. Perhaps the most damning claims come from those who question the actual, actionable value of all this data. Tim Hartford made this very claim in the *Financial Times* when he stated that "Big Data has arrived, but big insights have not" (Hartford 2014). Overall, it appears that most individuals are still trying to tell “the signal from the noise” when it comes to the ultimate value of these new “Big Data” technologies.

Thesis Question

Hype or not, it appears that “Big Data” is here to stay as a valuable commodity for the modern business organization. One area with extreme potential for disruption is the field of Supply Chain Management, a traditionally data-rich environment that has only recently begun to adopt the new technology. This paper will focus on the intersection of these two subject areas, and will strive to answer the following thesis question: “in what ways will the application of “Big Data” technologies create new value for global supply chains?”

It will also address the following sub-questions: 1) how have we gotten to this juncture of Big Data and supply chain management, 2) what are some of the most promising Big Data technologies with regard to SCM, 3) what processes within SCM are most ripe for disruption, and 4) what are the societal implications of the broad adoption of Big Data technologies.

Working Definitions

For the sake of remaing analysis, the following working definitions will be used:

1. Big Data – The “true” definition of “Big Data” is a somewhat controversial topic, though a frequently-cited McKinsey Study defines it as “datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze"(Manyika et al. 2011). These datasets may contain millions or even billions of rows and columns of both qualitative and quantitative information. Big Data is said to have frequently “three defining properties or dimensions…Volume refers to the amount of data, variety refers to the number of types of data and velocity refers to the speed of data processing” (TechTarget 2017).

Another important distinction is the difference in “structured” versus “unstructured” data. “Structured data” refers to data that is neatly organized into titled columns and rows, which allows it to be stored in traditional relational databases. “Unstructured data” is less easily defined, though it can be thought of as any forms of data that are not easily stored in traditional relational databases. Common forms of unstructured data includes videos, text, and metadata. Unstructured data is important as a matter of sheer size; one recent study by the International Data Corporation estimated that as much of 90% of ALL data is unstructured (Vijayan 2015).

2. Big Data Analytics – Big Data Analytics can be defined as:

> “Big data analytics refers to the strategy of analyzing large volumes of data, or big data. This big data is gathered from a wide variety of sources, including social networks, videos, digital images, sensors, and sales transaction records. The aim in analyzing all this data is to uncover patterns and connections that might otherwise be invisible, and that might provide valuable insights about the users who created it. Through this insight, businesses may be able to gain an edge over their rivals and make superior business decisions” (Techopedia 2017).

The field can be further subdivided into a) *descriptive analytics*, which “creates a summary of historical data to yield useful information” (TechTarget 2017) about the past and present, b) *predictive analytics,* which is “the practice of extracting information from existing data sets in order to determine patterns and predict future outcomes and trends” (Beal 2017) and c) *prescriptive analytics,* which is an area that is dedicated to finding the best course of action for a given situation” given the relevant information gained from both descriptive and predictive techniques. (TechTarget 2017).

3. *Supply Chain Management* – Supply Chain Management can be defined as:

> Supply chain management (SCM) is the active streamlining of a business' supply-side activities to maximize customer value and gain a competitive advantage in the marketplace. SCM represents an effort by suppliers to develop and implement supply chains that are as efficient and economical as possible. Supply chains cover everything from production, to product development, to the information systems needed to direct these undertakings." (Investopedia 2017)

This paper will primarily focus on the "information systems needed to direct [SCM] undertakings," as the relevant Big Data technologies represent a new era for such systems. It will also, for the sake of analysis, view SCM as being somewhat isolated from other business disciplines such as marketing and finance, when in reality they are extremely related. Section II will begin with a brief history of supply chain management that will build upon and expand this working definition to establish the appropriate context for later analysis.

Overview and Structure

Going forward, this paper will follow the following structure. Chapter II will provide summarize the history and use cases of Supply Chain Management and Big Data to provide context for their intersection. Chapter III will analyze the potential for SCM disruption through Block Chain integration. Chapter IV will focus on next-generation Sales and Operations Planning. Finally, Chapter V will seek to address some of the societal implications of the increased adoption of Big Data-related technologies, such as narrow automation and narrow AI.

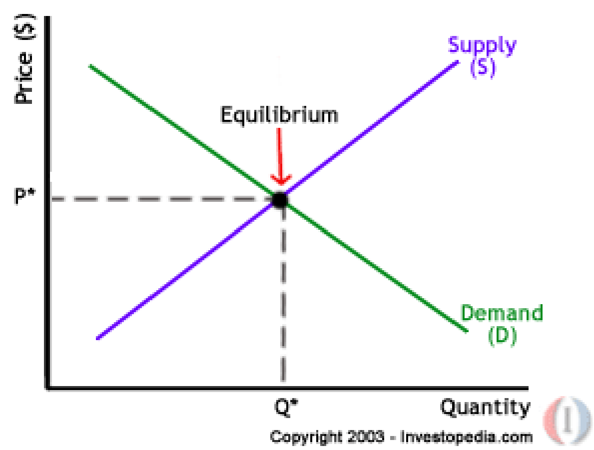
II. Setting the Stage: Supply Chain Meets Big Data

"What gets measured, gets improved."

– Peter Drucker, author and 'the founder of modern management"

A Brief History of Supply Chain Management

Supply Chain Management has existed in some form for as long as human beings faced scarcity in addressing their needs. This brings to mind the fundamental problem of matching supply with demand that underpins much of economics:



(Heakal 2014)

Supply chain management, as its name suggests, is tasked with providing for the upward-sloping supply line, where as other business functions such as marketing address the downward-sloping demand line. Other functions, such as finance, accounting, and legal, provide support to these core objectives (meeting supply and demand) in most instances. This applies broadly to both goods and service-producing firm, though is especially true of the goods-producing kind. This is because the supply chain drives much of value creation and competitive advantage for these firms.

SCM considerations are made wherever goods move, and humans have been moving goods for a very long time. Signs of early agricultural activity was recently identified in the

Levant region dating back beginning “some 23,000 years ago” (Snir 2015). The dawn of agriculture fundamentally changed how human beings lived, bringing them from subsistence hunter-gatherers to calculating cultivators of the land. Suddenly, humans had to make considerations for the storage and movement of their agricultural materials to meet increased harvests and populations. This led to numerous scientific and industrial breakthroughs, from simple machines such as the plow and waterwheel to civil structures such as levees and dams. Most of all, agriculture takes high levels of planning, both in terms of time (daily, weekly, and seasonal activities) and materials (seed, water, fertilizer). This need drove a fundamental transformation in how we *plan*, which is in many ways the underlying activity in supply chain management. In fact, the modern 365-day calendar has its roots deeply planted in the idea of tracking the agricultural seasons.

The two key drivers for further advancement in Supply Chain management beyond simple agricultural storage, movement, and planning were the somewhat-interlinked activities of war and trade. This linkage differs, however, in pre- and post-industrial societies. The noted Economist Paul Krugman argued that “war in the preindustrial world was and still is more like a contest among crime families over who gets to control the rackets than a fight over principles” (2015). The need for certain resources and the difficulties that arose in trading for them in pre-industrial societies drove armies to field out of economic necessity. Supply roads were created to support these armies in the field, and often persisted even after the war’s conclusion.

In post-industrial societies, this relationship inverts so that a *lack* of war facilitates economic gain. Industrialized weaponry acquired a destructive potential so vast that its use began to be avoided in order to prevent economic destruction. Furthermore, industrialized societies benefit from a combination of increased production, advanced trading abilities through stable currencies, and technologically-superior modes of transportation. The result is a world that is incentivized to avoid war and to seek trade if possible. This trend was especially evident in the post-WWII era of globalization, and was championed by individuals such as former Secretary of State and “father of the UN” Cordell Hull (Nobelprize.org 2014).

War as a Driver

War served to drive supply chain advancement as a matter of pure pragmaticism through the extreme nature of its demands. Noted business author Tom Peters stated:

> “Leaders win through logistics. Vision, sure. Strategy, yes. But when you go to war, you need to have both toilet paper and bullets at the right place at the right time. In other words, you must win through superior logistics.”

He was speaking in *Fast Company Magazine* about attributions of success following in the 1st Gulf War. Peters made the case that Gus Pagonis, the U.S. general in charge of logistics, should receive the credit usually bestowed upon Colin Powell and Norman Scwartzkopf for the war’s ultimate success (Peters 2002). Armies require vast supply chains to provide for their personal and equipment needs, from rations to medicine to bullets and tires. For example, a single roman legion operating in the field is said to have required “13.5 tons of food per month,” which would have been “impossible to source locally” through hunting, gathering and pillaging. Thus, the Roman army had to move enormous amounts of goods over immense distances to support its empire. It built a well-maintained system of roads for this very purpose, which was supplemented by the Roman navy (Heather 2005).

Modern armies face similar needs, albeit with more advanced technological means and analytical methods of fulfilling them. An entire subfield known as *Operations Research*, which overlaps closely with Supply Chain Management, arose to address the latter analytical methods. This field of applied mathematics sought to address "the complex requirements of World War II" through the "study of military logistics problems." Operations Research birthed numerous SCM-relevant theories, including a optimization theory, from a need to determine British radar installation locations, to scheduling theory, from a need to manage shipping logistics (Rajgopal).

Trade as a Driver

Trade is a more obvious driver for the development of supply chain management, as the two are nearly synonymous. Trade occurs when there is an exchange of goods to balance out shortages and surpluses. A farmer may have too much wheat, and a blacksmith too many tools; the two may exchange said items to reach a more useful equilibrium. Trade originally occurred through pure bartering (good for good), though it eventually began shifting towards a more standard medium of exchange. "Easily traded goods like animal skins, salt and weapons" became increasingly popular, until primitive forms of currencies in the form of small bronze figurines emerged "around 1,100 B.C." in China. These eventually shifted into round coins for ease of movement. Ancient Lydia's King Alyattes minted the first coin in 600 B.C. in Modern day Turkey, forming the basis of the modern money economy (Beattie 2016).

Trade routes between cities and nations created much of the modern map, as settlements and infrastructure developed along them to facilitate the flow of goods and services. Perhaps the most famous example of this was the "Silk Road," which was an ancient network of trade routes that lasted from 250 B.C. to the mid-1400s A.D. A massive amount of raw and finished good flowed over this route, from spice out of India and the Middle East to the namesake silk out of

China. Crucially, information also flowed over the route between travelers, connecting the East and West and benefitting both (Mark 2014). Another famous (and notorious) trade route was the “Triangular Trade” between Africa, the American colonies, and Europe. Slaves would move west after having been captured in Africa to North America and the Caribbean, where they were exchanged for Sugar, Tobacco, and Cotton bound for Europe, where were then traded for textiles, Rum and manufactured goods to be sent to Africa. This “circular supply chain” facilitated a major transfer of labor and goods that would change the futures of each of its respective participants (Boundless 2016).

No discussion of trade is complete without a discussion of absolute and competitive advantage. Absolute advantage refers to the “ability of a country to produce a greater quantity of a good, product, or service than competitors, using the same amount of resources.” Competitive advantage, on the other hand, refers to “the ability of a party to produce a particular good or service at a lower opportunity cost than another.” These two concepts are best explained through an example. One can imagine two countries, A and B, that produce two products, cars and bikes. The following chart contains their output of each products per day of work:

	Cars	**Bikes**
Country A	10	5
Country B	1	4

In this case, Country A has an absolute advantage regarding both Cars and Bikes, as it can produce more cars and more bikes than Country B with the same amount of resources/time. Country A, however, has an opportunity cost of producing bikes that is 2 compared to producing cars, whereas Country B’s opportunity cost is 0.25 versus cars. Therefore, Country B has a competitive advantage in cars. In terms of bikes, Country A has an opportunity cost of 0.5 bikes for every car whereas Country B has an opportunity cost of 4. Therefore, Country B will specialize in Bikes, Country A will specialize in cars, and both countries will trade with each other to enjoy the surplus (Investopedia 2016).

These basic concepts of absolute competitive advantage underlies many of the free trade policies that have dominated much of modern International trade. The logic goes: by encouraging countries to specialize in the goods that they have a competitive advantage in producing, and by promoting free trade policies between those countries to best take advantage of the specialization, then all will benefit through either reduced prices or better products. This sort of free-market thinking came to dominate the 20th century, forming the bedrock of the modern global economy. However, recent leaders in the 21st century have increasingly encouraged more protectionist policies that seek to quell this free trade.

A Brief History of Big Data

"Data," the plural of the word "datum" is a "collection individual facts, statistics, or items of information." Therefore, a more contemporary view of data as only "items on a spreadsheet or in a database" is not broad enough. Ancient spoken stories contained "data" to be passed onto younger generations and different peoples (Dictionary.com). The Sumerian people recorded the first known written language (data) in circa 3000 B.C., using logograms (non-linguistic symbols) on clay tablets (Archaeology 2016).

Writing (and data collection) gradually progressed across culture and mediums (from papyrus to paper) until the mid-15th century, when Johannes Gutenberg invented the first movable type printing press. This innovation facilitated the first mass-printed books, the famed "Gutenberg Bibles." From this point forward printing only improved, unlocking the potential for written data for the everyman (Kreis 2016). Literacy rates, which had previously hovered at around 30% in Europe, began to steadily rise as the written word became more and more common (Ludlow 2016). The rest of the world followed a similar trajectory, albeit from different starting points and at different rates.

As important as the written word and printing press were in the history of literacy and the spread of information, they are but a blip in the "history of data." The often-cited (and aforementioned) quote "90% of all the data in the world has been generated in the past two years" can be attributed to Petter Bae Brandtzaeg of the Norwegian research organization SINTEF. He was speaking in at a Statistics conference about the rise of data collection from Internet "unicorn" firms such as Facebook and Google (SINTEF 2013). The internet and its corresponding services has *created* a volume of data unlike the world has ever seen through user clicks, searches, and "likes."

One can use a simple analogy to frame the enormous difference in volume. If one compares data-creators to ships, then pre-internet writers are like canoes of varying sizes. They create a "wake" behind them of their written work, large in the case of books and articles and small if only letters or legal documents. Even the most prolific of data-creators in pre-internet history are still of the same class of boat, despite their "wake" being slightly larger (perhaps it is just an abnormally long canoe). Post-internet data creators would then be akin to battleships. Their "wake" is several magnitudes larger than that of their pre-internet forebears, as their every action online puts out an enormous stream of data. This means that even the least prolific post-internet creators still dwarf the most prolific pre-internet creators (at least in terms of volume, not necessarily quality).

The “Big Data” revolution would not be possible if not for massive improvements in both data processing and data storage. The next sections will provide a brief history of both.

Storage as a Driver

The ability to store data is central to its core function as a way of transferring information between interested parties. The initial information transfer began with spoken stories and oral histories that were passed between generations, as well as with ancient cave art via pictograms. The oldest known examples of human cave art were found in 2014 in a damp cave in Indonesia, and are believed to have been “at least 35,400 years old (Mott 2016). Similar forms of primitive, pictographic “storage” continued to be drawn on natural features, built walls, and clay tokens until circa 3200 BC, when the Sumerian people of ancient Mesopotamia began to use styluses to impress images onto clay tablets to count “agricultural and manufactured goods.” This primitive form of “data capture” gave birth to further and more advanced systems of information storage that eventually evolved into the kinds of written language that are now commonplace (Lo).

Various written languages and counting systems served as key facilitators for the growth of civilization and commerce for the next several thousand years. Writing utensils and receptacles advanced slowly, with the Chinese leading the way through their use of “block printing” on paper for both money and playing cards. This process used carved wooden blocks to repeatedly stamp written words and numbers in order to mass-produce books and other written documents. The “blocks” were easily damaged could not be adjusted quickly, so the overall price of printing remained relatively high. This all changed during the middle of the 15th century, when a former “stonecutter and goldsmith” named Johannes Gutenberg perfected an alloy that was both easily cast and durable. This allowed Gutenberg to produce cheap and easily rearrangeable type blocks that could then be used to mass-produce written works. He began his famous Bible project in 1452, which succeeded in bringing the Bible to the common man. Gutenberg's invention rapidly spread throughout Europe, plummeting the price of books (and therefore "data storage") while simultaneously causing literacy rates to explode (Kreis 2016).

The final major shift in data storage technology occurred in the 19th century and brought about the modern era of digital storage. Vlademar Poulson's invention of magnetic wire in 1899 gave birth to the first forms of working storage: magnetic tape in 1928 as well as the magnetic drum in 1932. Professor Fredrick C. Williams then invented the first random access memory (RAM) using a system of "electrostatic cathode-ray tubes for digital storage" known as the "Williams Tube" (1946). More advanced systems of storage such as the Hard Disc (1956), 8" Floppy Disc (1971), CD (1980), DVD (1995), and Microdrive (1999) brought digital storage into the present day. Now, the average personal computer comes with both a large amount of working memory as well as an incredibly small yet spacious solid state long-term memory system. Furthermore, "improvements in internet bandwidth and the falling cost of storage capacity" at the enterprise level gave birth to the storage "cloud," finalizing the commoditization of data storage via "near-infinite scalability" and "anywhere/everywhere data access" (Zetta 2016).

Processing as a Driver

The ability to process data is crucial in the sense that it "unlocks the potential" of data. The most basic processing systems arose out of evolutionary forces. The ability to critically think and to accurately remember provides immense evolutionary advantages in dangerous situations, and was one of the core drivers in early Human survival and propagation. The abilities to "store many decades worth of information; collect and process information, then deliver output, in split seconds;" and to "solve problems and create abstract ideas and images" have allowed us to become the apex predator for the entire planet (Smithsonian 2016). Our brains are still the preeminent information processing devices on the planet earth (at least in terms of flexibility), though this reign might potentially be coming to an end (to be discussed in later chapters).

While the overall rate of growth in our brain's processing abilities has somewhat slowed due to physiological limitations, our ability to augment it has not. The first known "counting table" originated on the island of Salamis in Greece, and was used to perform simple mathematical calculations. The bead frame abacus improved the concept by replacing stone "calculi" with sliding beads on vertical wires, though the overall idea of "boosting" human processing power remained the same (Young 2004). This technology "more or less stuck for the next 3,600 years," when the first slide rules were created in the 17th century to facilitate logarithmic scales for multiplication and addition. The first mechanical calculator was invented in 1642 by Frenchmen Blaise Pascal; it used geared wheels to carry out basic addition and subtraction. The four-function mechanical calculator followed in 1820 by another Frenchmen, Thomas de Colmar (Hazell). Basic mathematical processing was improved, though not by orders of magnitude over the human brain.

The final improvement in processing power came with during World War II as a matter of military necessity. Primitive machines such as the "Atanasoff-Berry Computer" were created to solve linear programs for military planning, though the machines had limited utility and were prone to malfunctions. The Electronic Numerical Integrator and Computer (ENIAC) was the first "general purpose" computer, meaning that it could be programmed to perform a variety of uses. The ENIAC "weighed 30 tons, and had 18,000 vacuum" for processing; it occupied an entire massive room, and required a substantial amount of electrical input. The ENIAC's successor, the UNIVAC, was made available for commercial use in 1951, and an entire industry was born.

Early companies such as International Business Computers (IBM) were the among the first to sell computational processing power to the masses, though the size and price tag of the early mainframe computers meant that they could only be bought by corporations and public institutions. The invention of the integrated circuit in the 1960's opened the door to the modern era of powerful, reliable, and – most importantly – portable computers. Microsoft invented the first operating system in 1980, while IBM brought the first personal computer to market in 1981 (Steitz 2006). The average consumer could now purchase a machine that substantially augmented their ability to consume, process, and produce information. Perhaps the simplest yet most startling example of this fact is the continued truth of Moore's law: computational processing power has *doubled* every two years since the computer's inception, and does not appear to be slowing down

Key Intersections of SCM and Big Data

The previous sections were offered to provide some historical context for the discussion to follow. SCM meets "Big Data" where more "traditional" means of data collection and analysis fail. As the "volume, velocity and variety" of data continues to increase, these "traditional" methods will only become more obsolete while "Big data" technologies become the norm. While there are numerous examples of meeting points between the two, this paper will focus on one key "bleeding edge" enabler, block chain technology, as well as one key process, S&OP planning, that have enormous potential for disruption.

III. Block Chain Implementation for SCM

"Fundamentally, a blockchain is good for helping parties that don't trust each other to share data very securely. In a supply chain, you have got these companies that are doing business with each other but aren't related and don't really trust each other, that must exchange goods and money."

– Travis Giggy, Head of International Business at Sku Chain

Introduction and Definition

The blockchain is newfangled and much-hyped technology that could be a key facilitator of the Big Data revolution within supply chain management. The blockchain is a "shared digital ledger, or a continually updated list of all transactions" that "occurs across a fully distributed or peer-to-peer network, either public or private." It is notable for its integrity, as its highly-distributed nature and strong cryptography makes it "nearly impossible to tamper with any individual transaction record without being detected" (Morrison 2015). Its potential SCM utility lies in the transparency the technology provides; with the blockchain, every good produced has its own unique "chain" of transactions, which can be used to trace that good from raw material to finished product. This blockchain might then be "mined" for all sorts of value, from predictive maintenance to quality control. The blockchain could provide a depth and clarity of data that has never before been seen in SCM applications.

History of the Blockchain

The blockchain can trace its roots to another, even more-hyped technology: bitcoin. In fact, it was not necessarily meant to be a valuable technology of its own right, but rather a necessary enabler of the crypto-currency. Bitcoin is the brainchild of a legendary and mysterious figure Satoshi Nakamoto, who is supposed to have lived in Japan and begun work on the concept in 2007. Subsequently, three individuals, Neal Kin, Vladimir Oksman, and Charles Bry, filed for a patent in 2008 for a new kind of encryption technology, which later became Bitcoin. Later that year, Nakamoto published a white paper entitled "Bitcoin: A Peer-to-Peer Electronic Cash System," which laid out the underlying design that solved the "crypto-currency problem" of double spending (crypto-currencies had long been theorized as a potential new form of legal tender) through his unique ledger system (which later became known as the blockchain).

The first bitcoin transaction took place on January 12th, 2009, which foreshadowed a major turning point in the currency's viability later that year when a formal exchange rate was established based upon the "cost of electricity to run a computer that generated Bitcoins." (historyofbitcoin.org). Bitcoin continued to legitimize through the early 2010's, despite a few high-profile crashes and thefts. It even began to garner attention from both mainstream media outlets and business organizations, and was even on the 2014 "top-five most-googled list" (Chen 2014). The blockchain came to predominance in tandem during this rise, having demonstrated its initial use case in keeping Bitcoin viable and secure.

Initial Example

In order to develop a preliminary understanding of the potential of Blockchain in an SCM context, please consider the following example: an American airplane manufacturer has chosen to implement the blockchain across its global supply chain as a means of managing inventory, insuring quality, and gaining testing data. It works with each of its sub-tier suppliers to utilize the shared ledger for tracking each-and-every parts. One such part might be an aluminum brace used in the plane's rear landing gear. The brace's first transaction is recorded when its drawn from the ground in raw form and its unique qualities – weight, size, quality – are stored. Additional transactions occur and are tracked at each subsequent industrial step, across both facilities and suppliers. This includes both steps the changes the part's form, such as casting and milling, as well as more "passive steps," such as storage and transportation. This insures a thorough and complete history of the part, which continues even after it is placed on the plane in production and put through real-world use. Every time the part is inspected, cleaned, or replaced, a transaction is recorded. If the part breaks and must be discarded, yet another transaction is recorded that may be referenced in the future by for predicting similar behavior in related parts. The brace may even be tracked in its post-consumer life, through recycle or resale transactions that produce yet further blocks.

Understanding Blockchain

Qualities of Blockchain

To truly understand the disruptive potential for blockchain technology, one must first understand how it works. One common description compares the blockchain to "an accountant's ledger," in which all transactions are recorded between parties. This is a somewhat apt comparison, though it might mislead one into thinking that the *ledger* is the blockchain (that is to say, the paper and bindings the make up the metaphorical book). In reality, the blockchain is the *transactions themselves.*

To further illustrate the distinction, one can consider the aforementioned Bitcoin technology. A bitcoin transaction between two parties does not deplete one party's balance and increase the others. There are no "pools" of bitcoins to be dipped into. Rather, the history of transactions of the bitcoins to be exchanged is used in place of a "balance."

The difference between traditional transactional technology and "blockchain" has been compared to the difference between traditional word processors such as "Microsoft Word" and shared processors such as “Google Sheets.” In the former, a traditional document is created and exchanged between parties as a “version,” which may be changed and/or edited to create a new version. This new version may be sent back to the original creator, at which point they have two distinct yet comparable versions of the document. The latter, shared word processors do not run into these sorts of discrepancies (assuming a solid connection to the internet). Rather, they update in real-time and are therefore always in “sync” between the parties involved.

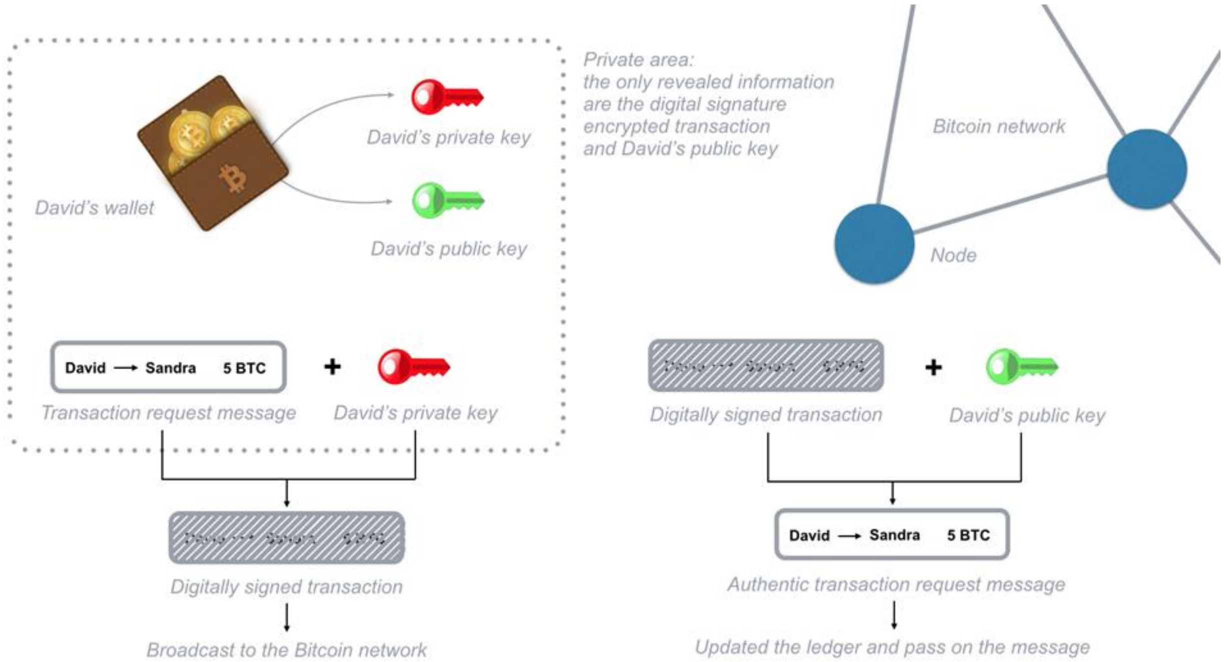
This shared quality creates a kind of “durability” that lies at the center of Blockchain’s usefulness. The technology is decentralized, meaning it cannot be “hacked” in a traditional sense nor manipulated by a single entity. Furthermore, there exists no central “point of failure” that could wipe clean the transactional history. The entire ledger system is updated and validated roughly every 10 minutes through an automatic self-auditing system (D'Aliessi 2016).

Structure of the Blockchain Network

The underlying “structure” of the blockchain resembles the internet itself in the sense that it is rendered as a network of computing devices, which are called “nodes”. Each device accesses the network through an installed “wallet,” and each participates directly by both validating (cross-checking ledgers) and relaying (broadcasting to all other nodes) transactions.

Every wallet is identified by a “public key” in the form a long stream of random numbers. This behaves like a “user address” for each wallet, which is used buy other “wallets” in the network to facilitate and validate transactions. The owner of a “public key” can be kept secret with care, though it is still somewhat subject to being traced through transactional triangulation. Every wallet also receives a “private key,” known only to the owner of the wallet. This private key behaves much like a password, allowing one total access to and some control over the contents of the wallet. Furthermore, this private key also can be used as a signature in verifying transactions, such as the exchange of bitcoins for goods.

The following pictograph is useful for understanding private and public keys:



Source: D'Aliessi 2016

The "dotted" area represents the "private area," in which only the seller's (in this case "David") public key and an encrypted version of the transaction is known by the rest of the network. Essentially, the network only know that some kind of transaction occurred and that "David" was involved. The buyer, "Sandra," must sign off to the transaction using her private key, at which point it is decrypted and its contents are updated to the total distributed ledger and tied to Sandra's public key (D'Aliessi 2016).

Components of the Blockchain

The namesake "block" is derived from the unit of information that is used to solve the fundamental problem of timekeeping. Each transaction that is tracked via Blockchain *cannot* be tracked using a traditional timestamp, as this information would be to easy counterfeit in the long-run. Therefore, timekeeping is necessary to prevent malicious users from partaking in transactions, receiving and verifying the goods they were promised, and then reverse the original transaction. Without timestamping, the network would not be able to distinguish the second transaction from the first, and would not be able to transfer "spent money" in the event of a disparity.

To solve this problem, the blockchain uses a "time-related" chain that sequentially links blocks to one another. For example, the first block would contain a single transaction, the second would contain two transactions, the third would contain three, and so on. The result is a tangled chain that can be undone if one simply analyzes the history of transactions; the one with the "longest" history is the newest block.

At this point, the blockchain hits an inflection point in terms of complexity. Blocks cannot be necessarily added by the machines who participated in the original transaction. Rather, for the sake of speed and to ensure validity, specialized machines within the network "compete" to add blocks by solving a complicated mathematical puzzle known as a "cryptographic hash function." Multiple transactions are converted into hashes and combined into a system known as a "Merkle tree," together forming a single "block" denoted by a single hash function (The Economist 2016). The mining machines then attempt to solve the problem at the expense of their processing power. This keeps the network of blockchains updating at the fastest possible rate, as the "winning" machines is "rewarded" not only with the chance to announce and place the newest blockchain, but also with some Bitcoin currency. Essentially, the machines are "selling" their processing power in exchange for the cryptocurrency, allowing the network of wallet nodes can operate in an efficient and secure manner.

Occasionally, multiple machines will solve the same "hash" function at once, and will both be able to validate/place a new block. In these instances, that particular blockchain is temporarily destabilized, as multiple copies exist that are all but identical except for the "newest block." This instability, however, should be quickly reconciled once the next transaction is logged, as the "longest blockchain wins" in instances of temporary discrepancy. The inherent complexity and random quality of the cryptographic hash function means that it is incredibly unlikely that the same computer can solve and place a block consecutively to the same chain. To put this into context, a machine or network of machines would have to 50% of the *total* computing power of the *entire* network to have a 50% chance of placing consecutive blocks.

Every individual block contains the aforementioned "list of transactions" (for all previous blocks), a proof of work" (a partial hash of the math problem solved to create it), and an approximate timestamp. The computational burden necessary to create a new "proof of work" (and therefore new block) increases with time, meaning that new blocks are continuously more difficult to produce than old blocks. The blockchain refers to a system of interconnected blocks that build upon one another using partial hashes. The "newest" block contains the transaction history of all blocks, and is linked to the second "newest" block via a partial hash. This method of relation continues down the chain (Culubas 2016).

Potential SCM Use Cases

Overview

The potential usefulness in an SCM context of Blockchain is currently "bleeding edge" in terms of mainstream implementation, though numerous firms (both established and start-up) are positioning themselves to innovate and profit in the space. One prominent firm, SKUchain, stated outright the potential for blockchain disruption of the SCM market:

> "We are talking about an $18tn (£12.6tn, €16.5tn) market dominated by antiquated, paper-based methods such as letter of credit and factoring; two approaches that between them account for about $5tn of annual trade today. Letters of credit have been around for hundreds of years and have not really changed. They work by couriering hard copies of documents around the world, while banks employ hundreds of people to review those documents."

Skuchain, for example, wishes to disrupt supply chain management by encouraged "collaborative commerce" between firms, in which the transparency enabled via Blockchain technology allows firms to utilize external synergistic relationships in a manner never before seen (Allison 2016). The following section will examine both this and several other SCM use cases for Blockchain technology.

Smart Contracts

"Smart contracts" are computer programs that execute pre-determined instructions depending on a given circumstance. For example, a "Smart Contract" in an SCM context might be a component of an ERP system that automatically orders more of a raw material input at a price that fluctuates with a pre-negotiated exchange rate. The "Smart Contract" validates, facilitates and tracks the transactional process via blockchain. The "validation" component is unique to the blockchain, as it uses the distributed functionality to insure the original tenants of the contract by simultaneously "checking" the contract across multiple nodes who also have a copy of the contract. This "usage" of the blockchain network will require a fee (it is non-essential to network existence/security), which may be paid via Bitcoin or standard currency and apportioned in the contract itself.

"Smart Contracts" have the additional benefit of being unambiguous. The logical realities of computer code limits the amount of "grey space" that can be present in a contract, as the program can only execute towards a singular outcome. This removes the constraints of "legalese" that, even in its best form, permits a level of ambiguity that can prove disastrous.

Supply Chain Auditing

Blockchain also has the potential to facilitate a depth and accuracy in Supply Chain auditing that has never been seen. Supply Chain auditing measures supply chain health against a set of predetermined requirements (Arter). It is one of the key ways that firms evaluate performance and risk within their supply chains, and is often conducted by a third party to mitigate bias. The Blockchain would serve as a "holy grail" of info to these third party firms, and could even render them irrelevant entirely. As Peter Drucker once said, "what gets measured, gets improved."

The blockchain-enabled good comes with total transparency of passage of ownership, as it comes replete with its entire transactional history. One can know who owned the good at any given time, all by having access to the private key associated with the good's wallet. This to solve the problem of instantaneous ownership between involved parties. For example, a heavy piece of machinery falls off a truck in transit and injures a pedestrian. The pedestrian sues for damages, though both firms have evidence indicating that the other party still owns the item and is therefore liable. If the good is blockchain-enabled, then any questions of ownership are immediately settled; no third-party or lawyer necessary. One would only have to check the distributed ledger at any node to know who owns the good in question. This same information capability may be granted to regulatory and/or insurance companies who also have a stake in the audit process.

The ability to audit becomes even more worthwhile if blockchain technology is enabled *within* the firm's production facilities, versus only at the natural points of exchange (point of purchase and point of sale). Every "touch" of item can be recorded, such as when it is moved within a distribution center or machined into another form. Existing technologies such as RFID and barcode scanners make be used to facilitate this process, and it all can be integrated with ERP systems. Once every transaction, both external and internal, has been recorded in this manner, risk and performance can be assessed with a newfound level of accuracy and clarity.

Predictive Forecasting

One unlikely though thought-provoking application of blockchain technology comes in predictive forecasting. Though this topic will be fleshed out with greater substance in Chapter 4, it is worth addressing at a high level at this point. One "school of forecasting" centers around the idea of "the wisdom of crowds." James Surowiecki wrote a much-cited book on the subject entitled *The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations*. In it, he argues that the aggregation of individual opinions of results in better decisions and more accurate forecasts. He believes that this is because the diversity of thought present in a crowd cancels out certain kinds of biases and error that serves as sources of distortion (Surowiecki 2004).

This sort of thinking has already been applied in SCM contexts, such as in the work of Bassamboo, Cui, and Moreno in their paper “The Wisdom of Crowds in Operations: Forecasting Using Prediction Markets.” Their approach utilized various prediction markets to “crowdsource” opinions on economic behavior, such as whether the price of a commodity would go up or down. They claim that a larger group size substantially improves the accuracy of the predictions. If this is true, such “crowdsourced” forecasts could be used to in demand planning in a supply chain context (2015).

Surowiecki lays out four conditions that must be met for the “wisdom of crowds approach” to be worthwhile:

1. Diversity of opinion – The opinions must come from a relatively diverse base.
2. Independence – The opinions of every individual are their own.
3. Decentralization – Every individual has access to the information they would need.
4. Aggregation – It is possible to aggregate the different opinions.

The blockchain is well-suited to meet these conditions. It is wide spread enough to reach a diverse base. Its users may act independently, and inherently have access to the world-wide web. Finally, and most critically, the distributed nature of the blockchain ledger facilitates ultimate aggregation. Furthermore, the system even has a built-in payment system (bitcoin) that may be used to incentivize predictions when necessary (Zafar 2016).

Internet of Things (IoT)

Blockchain better enables both existing and future “Internet of Things” devices to communicate with one another and the overall network. For existing SCM tracking technologies such as RFID and barcoding, the blockchain replaces existing centralized, server or cloud-based storage solutions that are vulnerable to physical shut-downs or cyberattacks. It also simultaneously solves the problem of validation and connectivity through blockchain's inherent functionality.

Going forward, the blockchain could facilitate a whole new era of machine-machine communication that could radically alter supply chain management. This is especially useful in activities that require mass coordination, such as in autonomous vehicles, as well as in tasks that require remote monitoring.

Autonomous vehicles could disrupt the inherent value structure of today's global supply chains. An incredible amount of money and time is spent coordinating in-house and third party logistics, including a significant portion going towards paying human labor. There are 3.5 million truck drivers in the United States, and the median income for a truck driver is $40,000 per year. Much of this cost could soon be replaced by autonomous vehicles from companies such as Otto and Tesla. These robot trucks must anticipate the behaviors of other vehicles on the road to avoid an accident, which is currently accomplished through a technology known as "computer vision." One of the best ways to improve this process is through communication, especially if both vehicles are entirely autonomous. The technology to broadcast such information has existed for decades, though the ability to store it in a meaningful way is relatively new. Cloud computing is a good place to start, as the cost of storage has decreased at incredible rates, though its centralized and corruptible nature makes it less than ideal. Blockchain can fill this gap, by allowing each vehicles behavior to be tracked and improved in a decentralized and secure way. The entire *network* could be coordinated by sharing real-time information regarding speed, location and destination, and could be improved by leveraging historical (blockchain) information to identify common trends and risks.

Remote sensing applications of IoT are useful in an SCM context when viewed through the lens of inventory management as well as procurement. A stock of perishable items could be tracked via blockchain, and could be set to release a notification whenever they are spoiled. This eliminates the possibility for supplier misconduct, as the entire network would be aware of the status of the goods in question. More general applications such as simple location tracking have already been discussed, though the inherent value of such a capability in the context of a global supply chain cannot be emphasized enough. IoT remote sensing impacts procurement in the form of a “smart machine” that can order its own material inputs via a preset “smart contract.” It might self-improve this process by dynamically recalculating its reorder point and economic order quantity once it has acquired sufficient data. The blockchain may be used to store this information, as well as to secure the identity and subsequent control of any machine involved in this process (Dickson 2016).

Production Planning

All the potential blockchain applications may be used simultaneously to improve one of the key activities in supply chain management: production planning. Though this is discussed in further detail in Chapter 4, a brief block-chain specific discussion is warranted here. Production planning is “the administrative process that takes place within a manufacturing business and which involves making sure that sufficient raw materials, staff and other necessary items are procured and ready to create finished products according to the schedule specified” (Business Dictionary). In short, it is the process through which supply is matched with (expected) demand.

Blockchain technology impacts this process by improving all components of coordination. Smart contracts make procurement of raw materials and labor far more efficient and far less ambiguous. Without ownership discrepancies and with good tracking, goods are ready for use on schedule. Forecasting may be improved through "wisdom of the crowd approaches," which are tracked and even incentivized through the blockchain. Finally, IoT technology is further enabled to both improve inventory practices (through decreased spoilage) and streamlined logistics (automated driving). The sum of these parts ads up to a production planning process that is more transparent, resilient, and cost-effective, all through the implementation of one single technology.

Total Collaboration

The final and most important use case for block chain technology in an SCM context is the potential for increased trust and collaboration between buyers and sellers. The issue of "trust" is one of the core issues between distinct firms involved in producing the same final goods. Buyers try and squeeze suppliers for the maximum quantity/quality at the minimum cost while also withholding critical information such as demand plans, which in turn incentivizes supplier misconduct as well as leads to inventory build-up (thanks to the bullwhip effect).

A greater level of supply chain value can be demonstrably realized through increased collaboration, as all sorts of cost synergies arise through production plan sharing and collaborative product development. This potential for collaboration is continuously eroded, however, by the core trust issues, squandering value for all.

The blockchain facilitates collaboration by solving the trust issue. When a buyer acquires a product, they also acquire its transaction history (assuming its blockchain-enabled). They may then hold both their immediate supplier as well as deeper sub tiers accountable for any issues on a transaction-by-transaction level. Suppliers, however, will not be incentivized to blockchain-enable their goods unless they think that they themselves will benefit.

There are two ways to promote their participation. One is to make it mandatory, akin to a "cost of doing business." Buyers may choose to only source from blockchain-enabled suppliers, especially if they have a relative size advantage or serve as major income streams. The second, and perhaps more ideal, arrangement comes via information sharing. In exchange for blockchain enablement from suppliers, buyers will reverse their own flow of information downward. They may provide components of their production plans and demand forecasts, while the supplier gives the entire transactional history of their good in return.

Potential Problems with Blockchain Technology

While Blockchain Technology is extremely promising, its hype does not come without criticisms. Several prominent voices have expressed doubts about the stability and scalability of the technology, while others have attacked its environmental impact and updating difficulties.

Potential for Gaming

Blockchain critics have most frequently cited its potential for "gaming," e.g. acquiring control of >50% of the network, as a core barrier to its widespread adoption. The original founder Nakamoto recognized the potential for this problem, and did his best to build the technology in a manner to prevent its occurrence (Economist 2016). Several smaller, alternative cryptocurrency networks that operate on blockchain technology have already been gamed in the manner. In fact, a group of Bitcoin miners briefly pooled enough computational resources in 2014 to take over the largest existing Blockchain network (Extance 2015). A pool that directly controls >50% of the network would be able to control the entire transaction ledger, nullifying its core values: decentralization and independence.

The risk of gaming may be mitigated by altering the core mining process to disincentive the use of pooling. By making it more dependent on computational RAM, such as in the case of cryptocurrencies such as "Litecoin," pooling becomes less effective and therefore less common. One promising firm, IC3, developed an alternative and unique approach to de-incentivize pooling; they created a currency that ensured the ability of pool members to "steal the reward for themselves without being detected." That way, no miner would be willing to trust another with any gamed rewards for fear of theft (Extance 2015).

Capacity Constraints

Another core problem with blockchain technology is its lack of computational capacity. Nakamoto limited the size of a block to one megabyte, or roughly "1,400 transactions." This means that the network can only handle "seven transactions per second." To put that into perspective, consider the fact that "Visa handles 1,736 transactions per second." Any increases to blockchain size would also come with a corresponding increase in propagation delay across the network, which would increase the risk of mismatching ledgers.

Currently, Bitcoin is facing this very problem. According to Kanaracus, "13 percent of transactions can take longer than 20 minutes, while 25 percent longer than an hour" (2016). Such delays cause problems in validation; a business might accept bitcoin from a customer in return for a good or service, only to find that the transaction was blocked 15 minutes later. Unfortunately, there does not appear to be promising solution to this problem at this point. The transaction and validation process will likely continue to a less than ideal amount of time for the foreseeable future.

Pointless Processing

Yet another criticism of Blockchain comes from environmentalists, who claim that the node validation system “adds up to a lot of otherwise pointless computing.” Since miners compete to solve a problem for a reward that they may, end the end, not receive, an incredible amount of computational power (and therefore electricity) goes to waste with each block added. In fact, active miners try “450 thousand trillion solutions per second,” and the best estimates range between two and 40 terawatt-hours (the difference between a county’s and a city’s energy usage) or energy usage to support the existing network (Economist 2016). This number will likely only grow as blockchain technology sees further adoption.

This “race” to solve math problem is essential so that each mining node has “skin in the game,” even if that math problem is essentially “arbitrary.” One promising solution involves having computers race to do “real work,” such as sequencing genes for medical use (Extance 2015). There are hundreds, if not thousands, of similarly computationally-burdensome problems that could benefit from a pool of powerful computers toiling night and day. Such use cases could deliver yet another application of blockchain technology.

Problems with Updating

The final recurrent problem with blockchain technology centers around its ability to update technology. Any changes to the network requires “community-wide agreement” within a group of disparate – and competing – parties. Experts have already cited the ongoing internal battle over how to best deal with the processing bottleneck, a looming threat to the entire network infrastructure (Economist 2016). If one set of users decide to “go rogue”’ to set up desired changes on a new network, they may encounter problems scaling it to a self-sustaining size (this has already occurred with several alternative cryptocurrencies.

Unfortunately, there does not appear to be many promising solutions to this problem. The inertia against network changes is inherent to the distributed model. This, in addition to some of the other aforementioned problems, will likely discourage some companies from fully integrating blockchain technology with their existing enterprise systems. The risk and lack of control may simply be too great for shareholder stomachs, especially in the near-term.

IV. Next-Generation Sales and Operational Planning

"The key to making a good forecast is not limiting yourself to quantitative information."

– Nate Silver, Author of *The Signal and the Noise*

Introduction and Definition

Supply and Operations Planning (S&OP) is the "means by which companies can align production with actual demand, through the merging of tactical and strategic planning methods across any number of organizational silos." It "takes into account product design, raw materials, manufacturing capacity, labor, finance, distribution, marketing, sales and customer service (Bowman 2011)." Sales and Operation Planning allows an organization to maximize its ability to behave a proactive versus reactive manner; by attempting to anticipate demand, it can better align the rest of its business to meet it. By using an accurate forecast as a "rudder," the best organizations can navigate treacherous and heavily-stochastic economic environments to achieve their operational goals.

The S&OP process requires major coordination across the firm, and is therefore far more successful when technology-enabled. Enterprise resource planning rose to prominence in 1990's to better facilitate general corporate coordination, and soon became integral to S&OP processes. Large vendors such as SAP, Oracle and Infor hold a dominant share in this industry due to the massive economies of scale that are inherent to the space. Concurrently, standalone S&OP-specific software solutions from vendors such as Llamasoft, Logility and JDA became available with integrative functionality. Many of the major ERP vendors have either acquired or built their own S&OP solutions, such as Oracle's Demantra, that can be better integrated and sold to supplement their existing stack.

Fundamentally, the S&OP process begins with a forecast. The forecast is typically rolling in nature, meaning that it looks out over a pre-specified "planning horizon" that adjusts forward as time progresses. This forecasting subdivided by period (e.g. four-week detailed outlook versus three-month general forecast) as well as de-aggregated by specific product family or stock-keeping unit (SKU). The most important feature of the forecast (besides its accuracy; to be discussed later) is its degree of organizational support. That is to say, the level of compromise and agreement between stakeholders in areas such as Marketing, Supply Chain, and Finance. Since an S&OP-enabled organization is "demand-driven" in terms of its decision-making, any psychological bias must be avoided at all cost when creating the forecast. For example, a sales-incentivized marketing department make interject a degree of forecast optimism that leads to subsequent supply-side issues, such as an increased bull-whip effect (to be discussed later).

Once a forecast is made and agreed upon, an operational plan must be implemented to generate supply. This is the key junction in which ERP systems become extremely useful; by fully understanding the firm's resource potential and current planning obligations, and operations team can best execute a feasible plan to meet incumbent demand. Decision-support and optimization techniques may be utilized in this period, as they allow a business user to "solve" for a best-case scenario depending on the situational constraints and objectives (to be discussed later). Once a demand-drive operational plan is created, the company shifts into the execution phase in order "make" and "deliver."

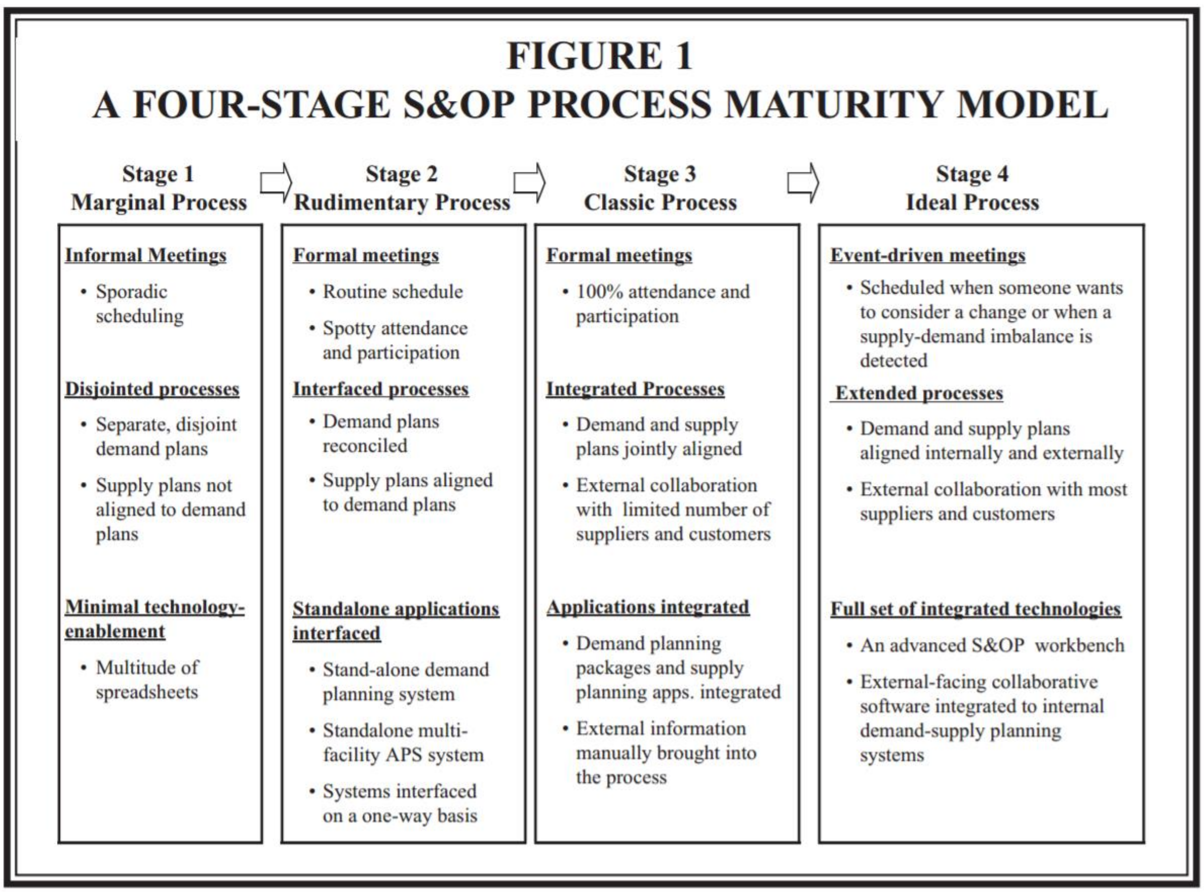
Additional Considerations

Outside of the core process associated with S&OP planning and subsequent execution, considerations should be made for additional capabilities that provide auxiliary support. Kinaxis, a cloud-based S&OP Software as a Service (SaaS) provider, provides a list of "four key capabilities" that should be provided for by a robust S&OP process:

1. Scenario Management – The S&OP process should incorporate "what-if" scenario modelling. This may be facilitated through means such as sensitivity analysis, in which one changes one or more input variables in a discrete or continuous fashion to determine end-state impact, and Monte Carlo simulation, which simulates numerous outcomes according to set means and variances to determine end-state expected values.
2. Financial Measures – The S&OP process should consider the financial limitations and implications associated with long-term planning. This includes but is not limited to cash-to-cash cycle, the time period between when a payment from a customer in exchange for inventory is made and when that cash is actually collected, as well as Net Present Value (NPV) calculations, which can dictate whether or not it is worthwhile to produce supply to meet expected demand.
3. Early Alerting – The S&OP process should clearly delineate Key Performance Indicators (KPIs) and set acceptability thresholds for each. An early alert system may then be instituted to give warning before the process becomes out of control (e.g. in the event supply will not meet predicted demand).
4. Management by Exception – The S&OP process should facilitate root cause analysis if the process go out of control. This may be enabled by KPI early alerting, assuming those KPIs are well-matched to the process. Managers should therefore be able to adjust the process accordingly by addressing each root cause.

The Four Stage Model

Furthermore, MIT's Larry Lapide lays out a diagnostic model for assessing the maturity level of a company's S&Op process in *The Journal of Business Forecasting*'s Spring 2005 edition. He used the following chart to lay out his model:



Source: Lapide, 2005

This framework is particularly useful in the context of this paper, as it is specifically designed to enable firms to identify their own level of maturity so that they can make more informed technological purchases to better enable the overall process.

The chart is self-explanatory in terms of general content, though Lapide does offer more nuanced analysis in his article. The Marginal Process Stage (I) is associated with minimal company buy-in as well a heavy reliance on spreadsheet-based planning. This results in a low amount of coordination and therefore performance. Lapide states that most firms that partake in S&Op planning are somewhere in between the Rudimentary and Classic stages (II & III).

In the Rudimentary stage, there is limited corporate buy-in to the overall process as well as some degree of interface. The supply and demand plans are still generated separately by their respective departments using their own standalone technologies, and the integration occurs when Demand Planning applications report "downstream" to the supply-side Advanced Planning and Scheduling (APS) systems. The information flow in this situation is one-directional, and therefore not heavily consensus-based.

In the Classic Stage, the Demand and Supply Planning occurs in unison to insure tight integration and successful execution. The company buy-in is high as both planning teams enter the process with "rough-cut" plans to be reconciled later towards a feasible consensus. Both the Demand and Supply-side software platforms are fully integrated, usually through an ERP system, and automatically update their combined plans should anything change with either the demand or supply situations. Finally, limited amounts of external information from either customers or supplier may be included in this type of planning to provide for greater levels of coordination and to facilitate cost synergies.

Finally, the "Ideal" Process Stage (IV) is the benchmark that all firms should strive to achieve. Lapide explicitly states that the "perfection" of this stage is inherently unattainable, though he also encourages firms to try for it nonetheless. The "Ideal" process is near-automatic; every system is fully-integrated and planning meetings are only necessary when triggered by an event (e.g. a weather event that could spike demand or limit supply). He suggests the use of what he calls a "workbench" (which appears to be like a standard business intelligence dashboard) to be used for monitoring the associated KPIs in real-time and performing root cause analysis/adjustment when necessary. He also suggests further customer and supplier integration in order to achieve external/internal coordination. (Lapide 2005).

At the time of its publication in 2005, Lapide's work on S&OP planning held the fourth "ideal process stage" as a benchmark that firms could strive towards. While it is true that this stage is demanding in its requirements, it might not necessarily be as "impossible" as Lapide once laid it out to be. Modern breakthroughs in Big Data technologies better enable existing ERP systems to meet a more demanding standard of supply and demand planning; the continued implementation of such technologies may allow firms engaged in S&OP to reach closer and closer to Lapide's "ideal."

Next Generation Demand Planning

Basic Time-Series Modelling

Time-series modelling is the essence of demand forecasting, as historical demand data is the closest proxy for estimating future demand. This is because the data is "serially correlated," meaning that changes in a previous and related period (such as the same month year over year) are associated with a period yet to come. Time-series models may also be spoken of in terms of attributes such as their level, or base point; trend, or gradual change over time; seasonality, or predictable increases/decreases associated with a fixed period; and cyclicality, or predictable increases/decreases associated with a non-fixed period.

The most basic time-series model is a simple moving average, in which one sums the levels over a set number of measurements and then divides the sum by that set number to take the arithmetic average. The models become more advanced as one moves into weighted moving averages, which give more bias to recent results in determining the average, as well as basic exponential smoothing models (single exponential), which begin to use smoothing parameters. The holts exponential smoothing model (double exponential) implements a smoothing parameter to capture trend, while the holts winters model (triple exponential) encapsulates seasonality as well. Exponential smoothing models are especially well-suited to non-stationary data sets, in which the mean increases or decreases as a function of time.

Beyond these exponential models, one begins to use autoregressive integrated moving average (ARIMA) models to better capture serial correlations when the data is stationary and "deep" enough (>= forty data points). The former, a data sets stationarity, can be resolved through a technique known as differencing, meaning that ARIMA models can be used widely with enough data depth. Their principle strength lies in their ability to create "mixed models" with both autoregressive and moving average parameters that better capture the structure of the underlying data.

Such ARIMA models were once considered "cutting edge" at an industry level, as the core statistics were well-known though limited by computational processing power. With the rise of distributed processing through services such as Amazon Web Services, the average business user with a decent computer can now run these more technical forecasting techniques. As a result, the "cutting edge" is pushed forward into models borrowed from other disciplines such as physics and economics (Hyndman 2014).

Demand Sensing

Demand sensing is "an advanced modeling technique that uses downstream demand signals, rather than past sales, as the basis for developing forecasts." It utilizes non-traditional (at least in a supply chain-context) data inputs to provide a more accurate forecast. These data inputs maybe "structured," which may be stored in an arrayed format such as in a relational database, or "unstructured," which may include text sources such as social media activity. Demand sensing is typically utilized in a short-term forecasting context; both traditional and non-traditional data inputs are gathered through sources such as social media postings and web searches, and the operational plan is adjusted accordingly (Brightwork).

For example, demand sensing may be used after the unexpected media endorsement of a product from a well-known source, such as a celebrity chef. This might cause consumer demand to "spike" in way that defies the traditional forecast (which was likely made months before), thus leading to stock outs and a low service level. Demand sensing-enabled organizations might be able to pick up on this "spike" through increased company social media "mentions" and even network ratings (one might expect a certain "percentage" of viewers to convert following endorsement). The affected organization can then react in a limited way (given the limited time horizon) to better match supply and demand by surging supply in target markets.

Machine Learning

Machine learning is a computational technique that "trains" a computer algorithm to predict certain occurrences or attributes. They are "trained" in these sense that they are not explicitly programmed to perform their end use case, but rather begin in a blank and flexible state that is then "shaped" through a steady diet of "training data."

In supervised learning, this "training data" consists of both inputs and their known outputs, which the computer analyzes to find underlying patterns and structures with predictive potential. The computer is then fed a set of "testing data" of only inputs to see how it performs when making predictions. Finally, the known outputs of the “testing” inputs are fed in to retune the algorithm towards greater accuracy. As time goes and the algorithm receives more and more data inputs with known outputs, it adapts to become better and better at its use case.

Unstructured machine learning, or “data mining,” follows a similar overall iterative process, though the crucial difference is that the algorithms do not receive an explicit set of output-mapped inputs for us in prediction. Rather, they are simply given their end goal and instructed to map their own inputs to the desired output. This can result in the discovery of “unexpected” relationships that would not normally be perceived by a human user, as the computer is both more computationally powerful as well as less prone to certain biases (Rouse 2016).

Machine learning can be applied to demand sensing by through both supervised and unsupervised techniques. In the supervised use case, historical inputs such as weather, holiday seasons, economic indicators, and political trends are mapped to demand levels as an output. A “sliding window” of past observations is then used to forecast future demand levels. As time goes on and periods repeat, the supervised algorithm “learns” increasingly nuanced structures with regards to the data and adapts accordingly. For example, it might switch between different levels of differencing in its ARIMA models depending on the period and data trends, or between types of modelling entirely. The algorithm knows when to do this by constantly checking the “measures of fit” of its models so that it constantly adjusts to the “better” model when available.

In the unsupervised use case, the end goal – an accurate forecast of future demand levels – is given to the algorithm along with access to massive swath of time-stamped potential data inputs. The algorithm then “chooses” for itself which inputs to map to demand levels as an output, even if the relationship between the two is not necessarily intuitive (at the human level).

For example, an unsupervised algorithm might pick up on the behavior of a sports franchise and use it as a predictor of demand levels for a consumer item that is not traditionally associated with that sport. If NFL team losses in a previous season are somehow predictive of certain types of book sales after the season is over, then the algorithm would pick up on the fact and exploit the relationship as a result.

A final and exciting potential "end state" for demand forecasting might be a dynamic combination of time-series forecasting methodology with demand sensing all built on a machine learning platform. This complex algorithm would constantly adjust its "sliding window" of historical data while also switching between the best time series model. It would also simultaneously integrate "sensed demand" into its short-term forecasts. Finally, it might utilize unstructured learning principles to continually search for and incorporate new inputs to improve both the short-term and long-term demand forecasts.

Next Generation Supply Planning

Once a demand forecast has been made, an organization can begin to construct its supply schedule for that time-period. Unless the organization is brand new, considerations must be made for the current production plan and commitments, as they will almost certainly affect the feasibility of any future scheduling. This section will not focus on the fine print of production scheduling and inventory management; rather, it will touch on a few areas that might be improved through the greater adoption of Big Data technologies.

Real-time dashboarding

Real-time dashboarding is a business intelligence solution that allows a firm to track its key performance indicators in real-time using a software application. Firms such as Microsoft with their PowerBI solution and Tableau have popularized the use of descriptive dashboards in recent years, and many of their customers have seen immediate financial results. These dashboards automatically “pull” data from the firm’s databases and visualize it in a compelling and easily understood manner. For example, the Boeing Company uses a version of this technology to provide visibility for its 787 airplane line’s supply chain, which spans across the entire globe across several sub-tiers of suppliers (Boeing 2017).

One potential supply chain-specific application of this technology is mitigating the legendary “bull whip effect.” This well-known phenomenon occurs when a demand forecast is distorted as it moves “up” a supply chain from consumer to the various sub-tiers of suppliers. The distortion usually originates from a lack of communication, such as in the case of a temporary price promotion to move inventory out of warehouses. The supplier sub-tier might interpret this temporary and artificial spike in demand as a signal to begin producing more, and end up building unnecessary inventory to meet an unsustainable level of demand.

Shared real-time dashboards may be used to mitigate this effect by allowing the direct-to-consumer firm to share demand data such as scheduled promotions or “sensed” demand spikes with their sub-tiers, who may then plan accordingly. Two problems that must be addressed in implementing this solution are the 1) lack of incentive to share demand “upstream” and 2) the potential loss of competitive advantage in doing so.

The direct-to-consumer firms do not necessarily benefit from this kind of collaboration with their sub-tiers, so those sub-tiers must instead negotiate a compromise to receive the information they need to better forecast. Furthermore, since many sub-tier suppliers also provide supply to competitors, the downstream direct-to-consumer firms might be concerned about a loss of competitive advantage through sharing their demand forecasts and promotional strategies. This risk may be mitigated through strict contractual information protections as well as through dashboards that provide only the essential information with sub tier suppliers. These sorts of dashboards directly resemble Lapide's description of the "workbenchs" that are found in ideal state S&OP planning processes.

Improvements in Automation

While industrial automation is a broad topic that does not always coincide with the Big Data technologies that are being considered explicitly in this paper, there are few applications that are dependent on Big Data solutions and directly relevant to supply chain management. The solution comes through the application of "computer vision" to an industrial production setting. Such technology has been pioneered through use cases in self-driving cars, which must "see" the real-world to navigate it. The technology is essentially a form of machine learning whose output is the successful reaction to an ever-changing set of real-world inputs. In an industrial setting, this technology allows for an increased flexibility in the automation of processes.

For example, a manufacturing robot equipped with computer vision can "see" and adapt to randomly placed industrial components as the parts travel down an assembly line. Previously, these components would have had to be placed in a highly-standardized fashion so that they could be easily picked up by the "blind" machine. Over time, the machine's "sight" will actually improve as it encounters more and more training data.

Another potential automation use case is the improvement in quality that may be achieved through machine-learned job enhancement. Industrial robots may be given a desired "output" – a certain good produced to a certain quality level – and allowed to pursue unstructured learning to determine how to best produce the product. This might allow a machine to improve towards a quality standard beyond what can be engineered by a human, or to meet an already existing quality level at a reduced cost.

Finally, the potential for office automation through Big Data technologies represents both a massive financial opportunity and potential societal cost. Predictive algorithms may be used to "automate" away many of traditional supply chain business roles, from procurement professionals using smart contracts to scheduling analysts who may be replaced by ever-improving ERP systems. This same trend will likely occur across all industries that implement Big Data technologies, as one analyst will now be able to do the work of many by monitoring the outputs of a set of algorithms. This kind of advance could also come with an intense societal impact, as the resulting job loss could further certain kinds of economic and political unrests (later discussed in chapter V).

Internet of Things

Internet of Things (IoT) was already discussed at some length in Chapter III, though it is worth specifically addressing in the context of production scheduling. IoT technologies allow for the real-time and highly accurate tracking of goods as the progress through a supply chain. This allows the production planner to control the process at a new level of granularity as they rapidly improve from shipment to stock keeping unit (SKU) level tracking. Individual SKUs may be RFID tagged and tracked based upon their production state (WIP versus finished good) as well as upon their location. Lost or spoiled inventory levels would plummet as a result, while all the meta data gained through the process could facilitate later improvements to it.

For example, factory locations associated with high levels of WIP inventory accumulation could be quickly identified as process bottlenecks and improved. The production facility itself could also be monitored in this way, through industrial robots that self-monitor their mechanical status or climate-controlled storage units that constantly auto-report their temperature and humidity levels. As detailed in Chapter III, blockchain integration could facilitate this entire process by providing an audited and incorruptible ledger of all occurrences.

Challenges to Reaching the Ideal State

Firms seeking to reach Lapide's "ideal" state of Sales and Operation process face no easy taks, though recent advances in technology should bolster their ability. They should first begin with bringing their forecasting procedures up to speed through the implementation of advanced time-series modelling techniques such as ARIMA, demand sensing when applicable, and machine learning as they grow more mature in these capabilities.

Once the demand forecast has been made, these firms should consider implementing Big Data technologies throughout their supply planning process. They may use shared real-time dashboards to control the process as well as to minimize the amount of coordination meetings necessary both within and between firms, though special attention should be paid as to which KPIs to track and what information to share. Process automation should be able to increase through applications of machine learning such as "computer vision," with the biggest gains coming though office automation and employee augmentation. The "Internet of Things" gives firms the power to track their process to a SKU and location level, while also providing a bounty of incredibly useful meta data that may be used to drive continuous improvement. Overall, the S&OP process is ripe for disruption through Big Data technologies; the more data-enabled the process becomes, the more it will allow firms to differentiate themselves from their competition.

V. Societal Implications of Big Data Technologies

"Thou shalt not make a machine to counterfeit a human mind."

– Frank Herbert, Author of *Dune*

Introduction

The previous two chapters tough on some of the more technical and specific applications of big data technologies in the realm of Supply Chain Management. While the practical implications are important, the more philosophical should not be set aside entirely. The term "Big Data" has recently appeared in news headlines in conjunction with terms such as "Artificial Intelligence" and "automation," and is perceived by some to be a legitimate existential threat to humanity's quality of life and even existence. Such critics speak of a "singularity" event, in the trough of "Big Data" feeds an artificial intelligence that becomes so flexible, powerful and complex that it threatens humanity itself.

Ted Kaczynzki, a math genius turned domestic terrorist known as the "Unabomber," was amongst the first to popularize this threat in his "unabomber's manifesto." Kaczynski had embarked on a decade long mail bombing spree that targeted technology and government-related individuals and institutions across America. As a condition of stopping, he mailed his work to the *New York Times* and *Washington Post* to be published; they obliged, and millions have read the rambling and dystopic work in the years since. One of the most-often cited sections comes towards the end, in which Kaczynski predicts the evolution of computer technology towards a state in which it is only understood by a select few mathematicians and computer scientists, who in turn enjoy a kind of technocratic dictatorship by controlling a society completely dependent upon said technology. Eventually, even the technocrats lose control after the computers self-improve themselves past a point where human minds can understand them, and eventually reach a “plane of consciousness” that brings about a singularity event (Kazcynski 1995). Other, less troubled voices have raised similar concerns since manifesto’s publication, though the topic has only recently gained mainstream media attention.

The Growing Threat

Automation, Robots, and Narrow Artificial Intelligence

While a true “a singularity”-style event is unlikely in the short-term given the current state of generalized artificial intelligence, related threats to our quality of life have already arrived. Perhaps the most pressing is the risk of “job automation” through robots and narrow A.I. Robotic automation is the natural successor to more “traditional” forms of productivity improvements; technologies such as the Henry Ford’s assembly line sought to squeeze the maximum output from a human worker, though only so much can be done once human dexterity and physiological needs become the limiting factor. Robots do not need to take bathroom breaks, and their dexterity has improved at astonishing rates in the past 50 years.

Blue collar jobs, which are those defined by hourly rates of pay and manual labor, were hit hardest by this wave of automation. For example, “75 percent” of the steel work force – one of America’s most storied blue collar industries – was replaced “between 1962 and 2005” by a “a technology called the minimill.” Ball State University reported similar blue collar job losses across all industries during the time period, 87 per cent of which can be directly attributed to automation.

This number might come as a surprise to some, as numerous recent media headlines have covered American job losses through outsourcing to low wage countries such as China and India. In fact, this very issue was a core focus of Donald Trump’s recently successful presidential campaign. Trump promised to stop signing "losing trade deals" such as the Transpacific Partnership and to also "bring American manufacturing jobs back." According to MIT, "2 to 2.4 million net jobs" were lost to waves of outsourcing in the early 2000's, though many more jobs never "left" at all. Instead, a far greater amount simply "disappeared" to a machine that still operates stateside, where transportation costs are minimized now that wage arbitrage is nonexistent (Miller 2016).

This blue-collar job loss extremely threatening to a society built upon supply-side economics and job identity. Our capitalistic system is hugely dependent upon the consumer's ability to spend money on material items, as it accounts for "68.8%" of our overall economic activity. Without steady wages, the blue-collar consumers who make up majority of the lower and middle classes do not spend beyond the bare minimum for survival; as a result, the entire economy begins to unravel. Furthermore, our society places an extreme emphasis on one's job title in determining societal position and personal identity. As we continue transitioning into a world with less blue collar jobs over, the individuals who once occupied the jobs suffer as they begin to question their societal position and struggle to find self-worth. It is hard to gauge the full disruptive potential of large scale automation, though blue collar job loss has major implications for a country's tax base, style of political rule and even its core social stability (Miller 2016).

This potential for automation does not stop with the destruction of traditional Blue Collar Jobs; "white color" jobs, or those defined by a knowledge-intensive and non-routine job, may be next to face automated replacement. Some of this automation has already occurred through simple software programs, such as in the instance of an ATM replacing some of the functions of a bank teller. Others are on the cusp of automation, as forms of "narrow AI" supplant humans in terms of job capability. These narrow systems consist of algorithms that are "trained" with relevant reams of data to perform specialized tasks, such as detecting fraud or analyzing X-rays. White collar job automation through algorithms could once again impact our economy and subsequent political stability in an adverse way, albeit in an even more magnified way due to increased levels of both influence and affluence.

Predicting the Short-term Specifics of White Collar Automation

It is useful to try and categorize the different types of white collar jobs by shared similarities when trying to predict which of them may be automated in the short-term. The following "buckets" draw their inspiration from the work Matthew Crawford, a philosopher and mechanic who has written at length about the nature of work. They are not meant to be mutually exclusive nor collectively exhaustive, though they do capture a useful underlying structure in terms of how white collar jobs deal with information:

Jobs That Summarize Information

People who hold these jobs are tasked with retaining and **summarizing** large amounts of information in exchange for money. Some good examples include teachers, librarians and (non-surgical) medical practitioners. These individuals spend years acquiring the information through schooling, and their monetary rewards are based upon their ability to extract useful information upon request and to then explain that information in a meaningful fashion. They are **most** at risk of automation in the short run, as machines can do **many** of their job functions with greater speed and accuracy. For example, a machine can accept a user's academic inquiry and relevant and directly-cited answer nearly instantaneously from the world-wide web. Furthermore, a machine might be better able to diagnose the disparate symptoms of a rare medical disorder through their superior pattern recognition.

Jobs that Synthesize Information

Individuals who hold these jobs are tasked with **synthesizing** large amounts of information inputs, identifying the underlying relationships as useful “insights,” and delivering a recommendation based upon their findings. Some good examples include lawyers, air traffic controllers and business analysts. These individuals receive monetary compensation based upon their ability to identify these fundamental relationships with speed and accuracy so that decisions may be made (such as a court’s verdict or an investment choice). They are at a **moderate** risk of automation in the short run, as machines can do **some** of their job functions with greater speed and accuracy. Once again, a machine’s superiority in pattern recognition comes into play when pulling insights from testing data (especially now that unstructured data such as written texts can be analyzed). A challenge still remains in making informed decisions in accordance with those insights, though it is conceivable that this may be automated as well with time.

Jobs that conceptualize information.

The final “bucket” of white collar jobs all center around an ability to **conceptualize** information where it did not previously exist. Some examples include scientists, research engineers, entrepreneurs and creative professionals such as artists. These individuals receive monetary compensation based upon their ability to generate new information through their own creativity or curiosity. They are at the **lowest** risk of automation in the short-run, as machines can do **a few** of their job functions with greater speed and accuracy. Machines struggle to succeed in these areas as they require logical leaps between the “known” and “unknown” that might not be clearly present in the testing data. Furthermore, in the instance of the creative professional, “success” is defined according to a subjective standard determined by the human user. Their work must appeal to a set of ethereal human desires that a non-human actor would struggle to capture.

Automation Versus Augmentation

Going forward, it appears that there are essentially two approaches towards dealing with topics of automation and job replacement. The first is "automator versus automated," in which a smaller group of individuals automate away a larger group of individual's job functions. The second is "automation versus augmentation," in which undesirable jobs are automated away to free up individuals to participate in more desirable jobs.

Automator versus Automated

The first approach, automator versus automated, is the current trajectory our society is on. There is an immense financial incentive to create means of replacing expensive human workers with their less expensive mechanistic counterparts. Numerous software engineers are employed in this capacity, and the entire field of automation engineering has emerged to service the demand. The primary defining characteristic of this approach is a small pool of workers whose productivity is essentially the sum of the workers they replace. For example, the creator of a machine the destroys the need for 3 full-time workers has essentially done the work of those three FTEs, making him three times more productive than any single worker. This individual may or may not be paid the equivalent of three FTE's wages, though either way the net number of jobs in the economy after the occurrence has likely decreased (individuals are still likely required to update and service the machine on occasion).

The secondary defining characteristic of this approach the gradual decrease of the pool of workers who are needed to do the automating. For example, if one automation engineer is empowered via improved technology to do the work of two, and the “size” of the pie of job automation opportunities stays the same, then another engineer will lose his/her job to the now consolidated productivity. The result of this secondary phenomena is an increasingly dwindling amount of highly-skilled and productive workers and an exponentially increasingly number of unemployed individuals. This, in conjunction with the resulting increase in the complexity of the machines themselves, takes our society in the direction the kind of “technocractic dystopia” that Kaczynski warned about in his manifesto.

Automation versus Augmentation

The second, and more preferable, approach to dealing with big data-driven automation is to automate away undesirable jobs so that we may become augmented in pursuing more desirable ends. Influential thinkers such as Elon Musk have championed this approach as a means of escaping a negative outcome regarding artificial intelligence and increased automation. By allowing ourselves to become “one with machines” through both supplemental and implantable technologies, we are no longer at odds with them. Rather, they continue to remain just another tool for use in our pursuit towards a more complete and fulfilling life.

Time is an individual’s most precious commodity; it is entirely nonrenewable, and a large portion of it is currently spent fulfilling obligations that are mandatory and yet not particularly “value-add” from an individual’s perspective. For example, an hour per day spent operating a motor vehicle to get to and back from a place of work often feels like time poorly spent; an individual must focus the bulk of his/her attention on the mundane yet dangerous task at hand. Supplemental machines solve this sort of problem; self-driving cars intake and process a massive stream of data from their surrounding environments to navigate the open roads. This frees up the human’s attention span to be used towards more productive ends, such as using that same time to finish a portion of his/her work. In the end, an hour of the individual's time is freed up to be used elsewhere. On a society-wide basis, the freed hours rapidly add up towards a more productive and happy future.

Augmentation occurs when we choose to interface with machines in a more direct way that directly improves our productivity and/or quality of life. Augmentation has occurred for as long as humans have used tools; even a primitive wheelbarrow augments an individual's ability to move heavy loads. Most modern tools are centered around processing information; when we send an email, we are augmenting our ability to share information. When we use a computer program such as Microsoft Excel, we are augmenting our ability to alter and synthesize information.

Currently, the chief limiting factor of these tools are the input and output devices we use to interact with them. Our eyes and ears operate as decent "input devices," though our ability to output is severely limited by speaking or typing speeds. Several companies, including Elon Musk's own Neuralink, are currently working on imbedded devices that are designed to increase our body's ability to both intake and output information into a machine. This will likely lead to various forms of direct connection that could eliminate the barrier between brain synapse and computer circuit. This "final" stage of augmentation will allow humans to harness the full computational power of modern (and future) computers to summarize, synthesize, and - most importantly – conceptualize information in a way never before seen.

Conclusion

In conclusion, this paper has provided historical context for both supply chain management and Big Data, offered an example of a crucial disruptive technology, examined a core process that is ripe for disruption, and summarized some potential societal implications of the trend towards artificial intelligence and automation. My research indicates that the field of supply chain management still has enormous potential for the continued implementation of Big Data technologies, especially when compared to the more mature fields of marketing and finance. Blockchain technology represents one of the most important faciliatory technologies, as it solves many of the core “trust” issues that have previously undermined supply chain collaboration. The S&OP process may be further improved towards an “ideal” state using better predictive and descriptive enterprise capabilities. Finally, the general trend towards the implementation of Big Data technologies brings forth a large amount of societal risk. If we fully integrate these incredibly disruptive tools within the confines of our society, we are potentially doomed to be supplanted by them. If we choose the augmentative route over the fully automated, we may instead prosper in ways never imagined.

Works Cited

"Advances in Data Storage Technology: A Timeline." *Zetta*. N.p., 5 May 2016. 07 May 2017.

This source provides a history of computer storage advancements.

Ainit Snir, Dani Nadel, Iris Groman-Yaroslavski, Yoel Melamed, Marcelo Sternberg, Ofer Bar-Yosef, Ehud Weiss. "First evidence of farming in Mideast 23,000 years ago." N.p., 22 July 2015. Web. 27 Feb. 2017.

This source details the origins of early agriculture.

Alan Morrison. "Blockchain and smart contract automation: Blockchains defined." N.p., n.d. Web. 27 Feb. 2017.

This source provides information on blockchain smart contracts.

Allison, Ian. "Skuchain: Here's how blockchain will save global trade a trillion dollars." *International Business Times UK*. N.p., 08 Feb. 2016. Web. 07 May 2017.

This source contains an interview with an employee from Skuchain.

Arter, Dennis. "How Auditing Supports Supply Chain." *MasterControl*. N.p. Web. 07 May 2017.

This source details the state and usage of supply chain auditing.

Bassamboo, Achal, Ruomeng Cui, and Antonio Moreno. "The Wisdom of Crowds in Operations: Forecasting Using Prediction Markets." *SSRN Electronic Journal* 2015th ser. 27. Oct (n.d.): n. pag.

This paper details a wisdom of the crowds" approach to forecasting demand.

Beal, Vangie. "Predictive analytics." N.p., n.d. Web. 25 Feb. 2017.

This source provides an overview of predictive analytics.

Beattie, Andrew. "The History Of Money: From Barter To Banknotes." *Investopedia*. N.p., 01 Feb. 2016. Web. 07 May 2017.

This source provides a history of currency.

"Big Data, for better or worse: 90% of world's data generated over last two years." *ScienceDaily*. ScienceDaily, 22 May 2013. Web. 07 May 2017.

This is the source of the famous "90% of data" quote.

"Bitcoin History: The Complete History of Bitcoin [Timeline]." N.p., n.d. Web. 27 Feb. 2017.

This source provides a history of Bitcoin cryptocurrency.

Bowman, Robert. "Think Tank." *What Is This Thing Called S&OP?* N.p., 25 Apr. 2011. Web. 07 May 2017.

This source provides a definition for S&OP.

Bughin, Jacques, James Manyika, Michael, Chui, Nicolaus Henke, Tamim Saleh, Bill Wiseman, and Guru Sethupathy. "The age of analytics: Competing in a data-driven world." N.p., Dec. 2016. Web. 25 Feb. 2017.

This source provides an overview of the disruptive potential of big data analytics.

Chen, Caleb. ""What is Bitcoin?" Is Google's 4th Most Searched 'What is?' Term of 2014." N.p., 20 Dec. 2014. Web. 27 Feb. 2017.

This source provides background information on Bitcoin.

"Cordell Hull - Biographical." *Nobelprize.org*. N.p., 2014. Web. 07 May 2017.

This source provides a biography of Cordell Hull.

D'Aliessi, Michele. "How Does the Blockchain Work? – Michele D'Aliessi – Medium." *Medium*. N.p., 01 June 2016. Web. 07 May 2017.

This source provides a very in-depth overview of the blockchain.

"Data." *Dictionary.com*. Dictionary.com, n.d. Web. 07 May 2017.

This source provides the definition of data.

Dickson, Ben. "Blockchain has the potential to revolutionize the supply chain." *TechCrunch*. TechCrunch, 24 Nov. 2016. Web. 07 May 2017.

This source touches on IoT applications of blockchain.

Editors, The. "The World's Oldest Writing." *Archaeology Magazine*. N.p., 6 Apr. 2016. Web. 07 May 2017.

This source provides the history of Sumerian logograms and early written languages.

Extance, Andy. "The future of cryptocurrencies: Bitcoin and beyond." *Nature News*. Nature Publishing Group, 30 Sept. 2015. Web. 07 May 2017.

This source details the risk of "gaming" cryptocurrency networks.

Hartford, Tim. "Big data: are we making a big mistake?" N.p., n.d. Web. 25 Feb. 2017.

This source provides critical commentary on Big Data.

Hazell, Alastair. "The history of the calculator." *The calculator site*. N.p. Web. 07 May 2017.

This source provides a history of the calculator.

Heakal, Reem. "Economics Basics: Supply and Demand." N.p., 20 Jan. 2014. 27 Feb. 2017.

This source provides the basic definition of a supply and demand graph.

Heather, P. J. *The fall of the Roman Empire: a new history of Rome and the barbarians*. New York: Oxford U Press, 2005. Print.

This source provides information on the logistical needs of a Roman legion.

"How to Best Understand Demand Sensing." *How to Best Understand Demand Sensing - Brightwork | Demand Planning*. N.p., n.d. Web. 07 May 2017.

This source explains demand sensing.

Hyndman, Rob. "6.1 Time series components." *Forecasting: Principles and Practice.* N.p., n.d. Web. 07 May 2017.

This source provides basic information on time-series forecasting,

James Manyika, Michael Chui, Brad Brown, Jacques Bughin, Richard Dobbs, Charles Roxburgh, Angela Hung Byers. "Big data: The next frontier for innovation, competition, and productivity." N.p., May 2011. Web. 25 Feb. 2017.

This source introduces the potential of big data.

Jayant Rajgopal. "Principles and Applications of Operations Research." N.p.Web. 27 Feb. 2017.

This source provides background information on Operations Research.

Kaczynski, Ted. "Industrial Society and Its Future." *The Washington Post*. WP Company, 22 Sept. 1995. Web. 07 May 2017.

This is copy of the Unabomber's Manifesto.

Kanaracus, Chris. "Don't believe the blockchain hype: Examining the weaknesses and risks." *ZDNet*. ZDNet, 13 Apr. 2016. Web. 07 May 2017.

This source details the risk of bottlenecking in blockchain.

Kreis, Steven. "The Printing Press." *Historyguide.org*. N.p., 2 May 2016. Web. 07 May 2017.

The article provides historical information for Gutenberg and the printing press.

Krugman, Paul. "Why We Fight Wars." N.p., 17 Aug. 2014. Web. 27 Feb. 2017.

This book provides an economic analysis of the reasons behind warfare.

Lapide, Larry. "Sales and Operations Planning." *The Journal of Business Forecasting* (2004): n. pag. Web.

This journal article examines the maturity of a firm's S&OP process.

Lo, Lawrence. "Sumerian." *Ancient Scripts*. N.p., n.d. Web. 07 May 2017.

This source provides more specifics on early Sumerian.

Ludlow, Lawrence M. "Johannes Gutenberg's Information Revolution | Lawrence M. Ludlow." *FEE*. Foundation for Economic Education, 24 Aug. 2016. Web. 07 May 2017.

This source provides literacy rates at the time of the Gutenberg bible.

Miller, Claire Cain. "The Long-Term Jobs Killer Is Not China. It's Automation." *The New York Times*. The New York Times, 21 Dec. 2016. Web. 07 May 2017.

This source details the history of American job loss to automation.

Mott, Jo Marchant Justin. "A Journey to the Oldest Cave Paintings in the World." *Smithsonian.com*. Smithsonian Institution, 01 Jan. 2016. Web. 07 May 2017.

This is the source of the earliest known cave paintings.

Olavsrud, Thor. "6 analytics trends that will shape business in 2016." N.p., 25 Jan. 2016. Web. 25 Feb. 2017.

This source provides an analysis of recent big data trends in business.

Patil, Thomas H. DavenportD.J., and Andrew McAfee and Erik Brynjolfsson. "Data Scientist: The Sexiest Job of the 21st Century." N.p., 05 Nov. 2014. Web. 25 Feb. 2017.

This is the source of the “data scientist as the sexiest job of the 21st century” quote.

Rouse, Margaret. "What is machine learning? - Definition from WhatIs.com." *WhatIs.com*. N.p., 2016. Web. 07 May 2017.

This source provides a definition for machine learning.

"Silk Road." *Ancient History Encyclopedia*. N.p., 28 Mar. 2014. Web. 07 May 2017.

This source provides a history of the “Silk Road” trade route.

"Brains." *Brains | The Smithsonian Institution's Human Origins Program*. N.p., 01 Mar. 2010. Web. 07 May 2017.

This source details the evolution of the human brain.

"Supply Chain Management - SCM." N.p., 22 Mar. 2016. Web. 27 Feb. 2017.

This source provides a definition for supply chain management.

"Competitive Advantage." *Investopedia*. N.p., 25 Mar. 2016. Web. 07 May 2017.

This source provides a definition for competitive advantage.

Steitz, Beverly. "Brief History Of Computer." *Brief History Of Computer*. N.p., 2006. Web. 07 May 2017.

This source provides a brief history of the computer.

Surowiecki, James. *The wisdom of crowds why the many are smarter than the few*. London: Abacus, 2014. Print.

This book details "wisdom of the crowd" forecasting techniques.

"The great chain of being sure about things." *The Economist*. The Economist Newspaper, 31 Oct. 2015. Web. 07 May 2017.

This source details the potential economic impact of blockchain adoption.

Boundless. "The Triangular Trade - Boundless Open Textbook." *Boundless*. Boundless, 20 Sept. 2016. Web. 07 May 2017.

This source details the history of the triangular trade.

Thompson, Collin. "How does the Blockchain Work (for Dummies) explained simply." *Medium*. The Intrepid Review, 02 Oct. 2016. Web. 07 May 2017.

This source introduces the blockchain.

"Timejacking & Bitcoin." N.p., Jan. 2016. Web. 07 May 2017.

This source details the problem of “timejacking” in relation to Bitcoin.

Tom Peters. "Rule #3: Leadership Is Confusing as Hell." N.p., 22 Apr. 2002. Web. 27 Feb. 2017.

This source details the role of logistics in military success.

Vijayan, Jaikumar. "Solving the Unstructured Data Challenge." N.p., 25 June 2015. Web. 26 Feb. 2017.

This source details the challenges and potential associated with unstructured data.

"What is 3Vs (volume, variety and velocity)?” *Whatis.com.* N.p., n.d. Web. 26 Feb. 2017.

This source introduces the “3 Vs” of Big Data.

"What is Big Data Analytics?” *Whatis.com.* N.p., n.d. Web. 25 Feb. 2017.

This source introduces big data analytics.

"What is descriptive analytics?” *Whatis.com.* N.p., n.d. Web. 25 Feb. 2017.

This source introduces descriptive analytics.

"What is prescriptive analytics?” *Whatis.com.* N.p., n.d. Web. 25 Feb. 2017.

This source introduces prescriptive analytics.

"What is production planning? definition and meaning." *BusinessDictionary.com*. N.p., n.d. Web. 07 May 2017.

This source provides a brief definition of production planning

Young, E.A. "A Short History of the Abacus." *A Short History of the Abacus*. N.p., 2 Sept. 2004. Web. 07 May 2017.

Zafar, Samee. "Blockchain and the future.." *Finextra Research*. Finextra, 30 Nov. 2016. Web. 07 May 2017.

This source connects. blockchain and wisdom of the crowd forecasting.

Biography

Levi Joseph was born in Atlanta, GA where he grew up on the banks of the Chattahoochee river. He double majored at the University of Texas at Austin in Plan II Honors and Supply Chain Management with a focus on data analytics.

While in school, he was involved with the UT Rock Climbing Team, The Tejas Club, and Texas 4000 for Cancer. Levi also worked as a teaching assistant for Professor Michael Hasler in the IROM department.

Going forward, he would like to pursue higher education and a career in data science. He is particularly interested in applications of blockchain technology, predictive forecasting, and mathematical optimization.

In his spare time, Levi enjoys lifting, running, yoga and cooking. His favorite Plan II experience was releasing a baby sea turtle into the wild while on a biology field trip in Port Aransas.